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Options for the Treatment/Destruction of Polychlorinated Biphenyls (PCBs) and PCB-contaminated Equipment.

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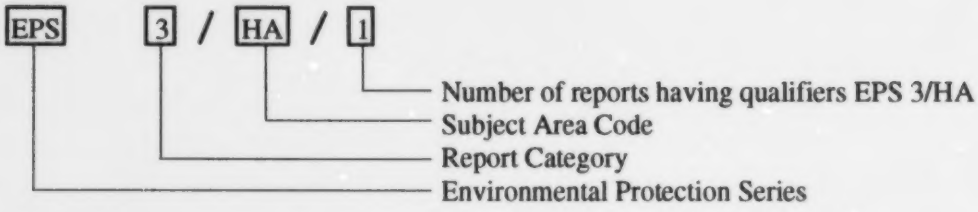

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Options for the Treatment/Destruction of Polychlorinated Biphenyls (PCBs) and PCB-contaminated Equipment

by

Proctor & Redfern Limited

for the

Office of Waste Management
Environmental Protection
Conservation and Protection
Environment Canada

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Comments on the content of this report should be addressed to:

Mr. Dave Campbell
Office of Waste Management
Environmental Protection
Conservation and Protection
Environment Canada
Ottawa, Ontario
K1A OH3

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Review Notice

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Abstract

This report provides options for the treatment and destruction of liquids and equipment containing polychlorinated biphenyls (PCBs). In addition, waste transformer and capacitor decontamination and destruction technologies are described and recommended options provided.

Résumé

Le présent rapport présente des options en vue du traitement et de la destruction des liquides et de l'équipement contenant des biphényles polychlorés (BPC). On y décrit aussi des techniques de décontamination et de destruction des transformateurs et des condensateurs électriques, et on présente les options recommandées.

Table of Contents

Abstract v
Résumé vi
List of Figures ix
Conclusions and Recommendations x

Section 1
Introduction 1

Section 2
Options 2
2.1 General Comments 2
2.2 Contaminated Mineral Oil 2
2.2.1 Treatment Technology 2
2.2.2 Treatment Options 3
2.3 In-service Contaminated Mineral Oil Transformers . . . 4
2.3.1 Decontamination Technologies 4
2.3.2 Decontamination Options 5
2.4 In-service Askarel Transformers 6
2.4.1 Decontamination Technologies 6
2.4.2 Decontamination Options 8
2.5 Waste Transformers 9
2.5.1 Decontamination Technologies 9
2.5.2 Decontamination Options 10
2.6 Capacitors 11
2.6.1 Decontamination and PCB Destruction Technologies 12
2.6.2 Decontamination and PCB Destruction Options 12
2.7 Askarel 12
2.7.1 Destruction Technology 12
2.7.2 Destruction Options 13

References 15

Appendix A
Canadian Stationary PCB Destruction Facilities 17

Appendix B
U.S. PCB Phase-out Program and Disposal Options 19

Appendix C
Mineral Oil Transformer Decontamination Methods 23

Appendix D
Commercial and Near-commercial Mobile/Transportable PCB Incinerators **25**

Appendix E
Decontamination Technologies for Waste Transformers **39**

List of Figures

1 Flowchart for Mineral Oil Transformer Decontamination Alternatives 7

Conclusions and Recommendations

General Comments

- PCB destruction/decontamination technologies are available to treat Canada's PCB inventory, and the private sector is ready and willing to service the market, given the appropriate regulatory climate.

- In Canada, the small market and the often lengthy technology and site approvals process have made hazardous waste service companies wary of entering the market.

- The U.S. experience in PCB phase-out and destruction has illustrated the importance of a clear, concise national legislative framework to which PCB generators and PCB service companies can respond.

Contaminated Mineral Oil

- Approximately 40 million litres of contaminated mineral oil are in use and 5.4 million litres are in storage in Canada.

- Mobile technologies to treat the PCB-contaminated mineral oil chemically are well proven and commercially available. Over 10 million litres of contaminated mineral oil have been treated in Canada since 1983.

- Four companies in Canada operate mobile chemical treatment systems and are approved for operation in most provinces. They have the combined capacity to treat all of Canada's contaminated mineral oil within 2 to 3 years.

- Government agencies of all jurisdictions must continue to facilitate the mobile chemical treatment of PCB-contaminated mineral oil by resolving issues of transportation, inventory consolidation, and regional facility siting.

- The private sector should be encouraged to handle all aspects of PCB-contaminated mineral oil treatment.

In-service Contaminated Mineral Oil Transformers

- Canada has in service approximately 310 000 pole-mounted transformers (capacity generally <500 L) and 25 000 larger distribution and power transformers containing PCB-contaminated mineral oil.

- Several steps are usually involved in the assessment and decontamination of these transformers, including a testing program to identify noncontaminated, low-level contaminated (<1000 ppm), and highly contaminated (>1000 ppm) mineral oil transformers.

- Small in-service transformers with low levels of contamination can be decontaminated using one of the retrofilling processes.

- Large in-service transformers with low levels of contamination can be decontaminated by retrofilling or by on-line mobile chemical treatment (in either an energized or de-energized mode).

- Highly contaminated in-service transformers can require several retrofills of clean oil or mobile treatments to decontaminate them. Alternatively, it may be more economical to scrap the transformer and replace it, depending on a variety of factors, including the remaining life expectancy of the transformer.

- Decontamination technologies for in-service mineral oil transformers are well proven in Canada.

- Government agencies of all jurisdictions must continue to cooperate to facilitate the use of mobile transformer decontamination technologies.

In-service Askarel Transformers

- There are approximately 7000 in-service askarel transformers in Canada.

- Only two options are available for dealing with in-service askarel transformers:
  - decontamination of the transformers using one of the U.S.-developed reclassification technologies, or
  - replacement of the transformer.

  The choice is based primarily on economics.

Waste Transformers

- Approximately 4000 askarel transformers and 3000 contaminated mineral oil transformers are in storage awaiting disposal.
- The best method of disposing of these transformers is decontamination by solvent flushing followed by metal recovery/smelting.
- Decontamination can be done using mobile or fixed systems—some combination is appropriate for Canada.
- In Canada, few provinces have developed decontamination criteria and testing methods for waste transformers.
- For the solvent-flushing method to become widely used, consistent decontamination Canadian criteria will need to be developed (e.g., through the Canadian Council of Ministers of the Environment).

Capacitors

- Approximately 200 000 PCB capacitors are in service in Canada; 110 000 are in storage.
- In addition, approximately 60 million small capacitors are in service in light ballasts.
- High-temperature incineration of shredded capacitors is the only approved destruction method.
- Mobile incineration of capacitors is the logical destruction strategy.

Askarel

- Askarel represents the largest amount of PCBs in Canada on a pure PCB basis.
- Approximately 20 000 t of askarel are in service and in storage.
- The only approved method of destroying askarel is by high-temperature incineration.

- The Alberta Special Waste Treatment Centre at Swan Hills has the only stationary incinerator approved for PCB destruction in Canada and is currently available only for Alberta's PCBs.

- Other stationary PCB incinerators are in the planning stages, but are not likely to be available for at least 4 to 5 years.

- Mobile/transportable PCB incinerators have a proven track record in the United States and are the best immediate solution for the destruction of the Canadian inventory of askarel.

- Four U.S. companies, with a total of seven mobile incinerators, have been approved by the U.S. Environmental Protection Agency for destroying liquid PCBs.

- A single large mobile/transportable incinerator could destroy the entire Canadian inventory of askarel in approximately 4 years of operation at one site.

- The siting of mobile/transportable incinerators is critically important; the siting process must assess the public acceptance of small mobile incinerators at many sites versus large transportable incinerators at a limited number of sites.

- Because of the priority of destroying askarel and the difficulties associated with siting mobile/transportable incinerators, it is recommended that the federal government play a lead role in providing suitable sites.

Section 1

Introduction

Following the Saint-Basile-le-Grand fire in August 1988, the Federal Minister of the Environment announced an action plan to destroy PCBs in use or stored at federal facilities across Canada.

This report investigates and evaluates the technologies available for the treatment/destruction of

- PCB-containing equipment,
- askarel, and
- PCB-contaminated mineral oil,

and develops options for the destruction/decontamination of PCBs and PCB-contaminated equipment.

Although the report was intended to assist the federal government in managing its own PCB destruction program, all of Canada's PCB treatment/destruction requirements were considered. This report is a guide only to currently available technologies; each PCB disposal situation will require a specific evaluation and solution.

Only PCB treatment/destruction technologies that are commercially available or nearing commercial availability were considered. To be considered commercial, the technology must have operated successfully under sustained, routine field conditions on a commercial scale and must have received regulatory approval.

Fixed facilities outside Canada were not considered for the following reasons:

- United States regulations (Code of Federal Regulations, 40 CFR Part 761) since May 1, 1980, prohibit the import or export of PCBs (>50 ppm) and
- the export of PCB waste from Canada is banned (PCB Waste Export Regulations, Canada Gazette, Part II, Vol. 124, No. 17, p. 3397).

The only stationary PCB incineration facility operating in Canada is at Swan Hills, Alberta. Because approvals for the construction of other stationary incineration facilities in Canada have been progressing slowly, the focus of this investigation was on commercially available mobile or transportable treatment/destruction technologies or technologies that could be readily used in Canada.

Mobile incinerators are small systems, usually less than 2 t/h capacity, which require less than 2 weeks to assemble on site, whereas transportable incinerators are larger, systems usually 5–10 t/h capacity, which require 6 weeks to assemble on site.

The PCB treatment/destruction options described in this report were developed by matching the capabilities of proven PCB treatment/destruction technologies with the Canadian PCB inventory of equipment, askarel, and mineral oils. Since there were too many different combinations of waste types, generator size, and locations to develop detailed strategies, a generic approach was taken in most cases.

Earlier reports prepared for Environment Canada (1983, 1989), which "cast a wide net" in identifying PCB destruction technologies for evaluation, were reviewed and, where appropriate, the information was updated.

Section 2

Options

The success of any PCB phase-out program will depend to a significant degree on the availability in Canada of PCB treatment/destruction facilities. This section describes the Canadian inventory of PCB wastes, the technologies available for their treatment/destruction, and strategies for implementing the technologies.

2.1 General Comments

The Alberta Special Waste Treatment Centre at Swan Hills is the only operational and commercial stationary facility in Canada. However, it is available only for the destruction of Alberta's PCBs. This report assumes PCBs located in Alberta will be disposed of in this facility and that the facility will not play a role in the disposal of PCBs located outside Alberta.

Another stationary facility, which is in the advanced planning stage, is the Ontario Waste Management Corporation's (OWMC) facility planned for a location near Bismarck in southern Ontario. Descriptions of the Swan Hills facility and the planned OWMC facility are provided in Appendix A. British Columbia has also made initial plans for a hazardous waste facility.

PPM Canada has a stationary chemical treatment facility in Saskatchewan for PCB-contaminated mineral oil using the same technology as its mobile units (see Section 2.2).

Most of the technologies used or available for use in Canada today or proposed for use in the future were developed in the United States for its own markets. These technologies were developed in response to the U.S. PCB phase-out program and approved methods of disposal as regulated in the Code of Federal Regulations, 40 CFR Part 761 (under the U.S. Toxic Substances Control Act [TSCA]). The U.S. phase-out plan and current PCB phase-out and disposal practices in the United States are described in Appendix B.

The U.S. PCB phase-out and disposal program appears to be progressing well. One of the main reasons for this success was the early adoption of clear, concise, and consistent national legislation to regulate this program.

2.2 Contaminated Mineral Oil

Approximately 40 million litres of PCB-contaminated mineral oil are in use and 5.4 million litres are in storage in Canada. This subsection deals only with the chemical treatment of PCBs in mineral oil and not with the decontamination of mineral oil transformers.

2.2.1 Treatment Technology

Mobile chemical treatment systems for PCB-contaminated mineral oil have been operating in Canada on a commercial basis since 1983. They have operated in nine provinces and have treated over 10 million litres of contaminated mineral oil.

Companies operating in Canada under various federal or provincial permits can be regarded as having proven commercial technologies.

These permits limit the maximum concentration of PCBs in the untreated mineral oil. The chemical treatment industry estimates that over 75% of all contaminated (>50 ppm) mineral oil transformers have PCB concentrations <500 ppm and 95% have PCB concentrations <1000 ppm. The PCB chemical treatment industry has designed its equipment to meet these market conditions.

The chemical treatment systems operating in Canada are permitted to treat PCB-contaminated mineral oil containing a maximum initial PCB concentration of up to 14 000 ppm, depending on the process. All the systems must guarantee that the mineral oil is decontaminated to ≤2 ppm.

In Canada and the United States, most mobile chemical treatment units use technology based on the use of sodium, which reacts selectively with the chlorine of the PCB molecule to produce sodium chloride and a nonhalogenated biphenyl. A chemical treatment process using PEG/KOH (polyethylene glycol/potassium hydroxide) as the reagent is also becoming widely used.

In Canada, PPM Canada, Rondar, Sanexen International, and ENSR Operations (formerly Sun Environmental) operate commercial mobile chemical treatment units.

Chemical treatment companies usually offer a range of services, many of which are specifically for the decontamination of mineral oil transformers. These services are described in Section 2.3.

2.2.2 Treatment Options

Currently, the market for treating PCB-contaminated mineral oil is well serviced by four companies operating a total of five to nine rigs (some rigs service both sides of the U.S./Canada border), depending on demand. With the nine rigs each operating at an average maximum capacity of 2.25 million litres per year, 20.25 million litres of mineral oil per year could be treated. With this maximum rig capacity, Canada's inventory of 44 million litres of contaminated mineral oil could be treated in 2 to 3 years. This does not take into account several important factors and assumptions, including the logistics of testing, draining, and refilling about 335 000 contaminated mineral oil transformers in service that contain most of this oil.

The demand for contaminated mineral oil treatment would increase significantly if mineral oils were part of an accelerated phase-out program. The companies currently servicing the market would likely accommodate the increased demand by constructing additional mobile rigs (4- to 6-month construction period at $500 000–$800 000 per unit). The often lengthy technology approvals process at the provincial level would probably discourage new entrants to an already competitive market.

The use of mobile chemical treatment systems is usually cost effective if more than 10 000 L can be treated at one site. For PCB generators (i.e., the current owner or person, company, or agency responsible for the PCB material) with <10 000 L at any one location, consolidation of PCB materials can be a cost-effective approach. In addition, generators should be allowed and encouraged to cooperate to make the most cost-effective use of contracted mobile equipment by arranging for cooperative, centralized treatment sites in their immediate geographical area. Some provincial governments allow this practice by permitting storage (inventory) consolidation and the associated PCB transportation.

Because of potential environmental liabilities, finding generators to host the facility may be a problem.

The chemical treatment industry would prefer to establish its own "semi-permanent" sites for its mobile equipment. In this way, both small and large generators could be serviced economically. PPM Canada has such a facility in Saskatchewan. Other attempts to establish permanent or semi-permanent sites for mobile chemical treatment facilities in Canada have met with approval delays. Provincial governments should be encouraged to streamline the approval procedures for this alternative.

Costs for mineral oil treatment range from $1.00/L for high-volume, local, bulk oil treatment at low initial PCB concentrations to $5.50/L for small-volume contracts and/or remote locations. Typically, bulk contracts are $1.50 –$2.00/L.

In summary, PCB-contaminated mineral oils can be adequately and cost-effectively treated by existing mobile chemical treatment companies with the addition of a few semi-permanent sites for mobile facilities to service small generators.

2.3 In-service Contaminated Mineral Oil Transformers

Approximately 310 000 pole-mounted transformers (capacity generally <500 L) and 25 000 larger distribution and power transformers with PCB-contaminated mineral oil are in service in Canada.

2.3.1 Decontamination Technologies

All the technologies currently used to decontaminate in-service contaminated mineral oil transformers involve methods that replace the transformers' contaminated oil with clean oil.

Standards set or accepted by provincial governments (by regulation in Ontario only) for the decontamination of mineral oil transformers basically rely on what is referred to as the 90-day test. The mineral oil in the transformer is tested 90 days after decontamination to verify that it contains <50 ppm PCBs. If the test results show <50 ppm, the transformer is considered to be a non-PCB transformer.

The 90-day waiting period is necessary because of "leach back." None of the decontamination methods is able to completely rid the interior of the transformers of all PCBs. Residual PCBs are found absorbed in the wood and paper materials of the transformer and in contaminated mineral oil trapped in small interior spaces of the transformer. After clean mineral oil is added to the transformers, these residual PCBs leach out of the contaminated materials into the clean oil. This leaching process is usually complete after 90 days in an operational transformer.

There are several decontamination methods available, the choice of which depends on

- the initial PCB contamination level,
- the requirements, if any, to keep the transformer energized (i.e., no shutdown allowed), and
- the number and size of transformers.

The initial PCB contamination will affect the 90-day test results. For any particular decontamination method, the higher the original PCB concentration, the higher the 90-day test result. Therefore, a decontamination method must be chosen that

will guarantee that the mineral oil will be <50 ppm after 90 days. As a rule, the cost of decontamination rises with increases in the initial PCB concentration.

Some industries and government services cannot readily or economically accommodate shutdowns of critical power supplies. Therefore, the ability to decontaminate energized transformers may influence the choice of methods. The cost of decontaminating energized transformers will be more than decontaminating de-energized ones.

The number and size of transformers play a major role in selecting the most economical methods (once the other selection criteria are satisfied). Methods that are economical on large transformers (capacity >10 000 L) or groups of medium-size transformers are usually not economical on pole-mounted transformers (capacity generally <500 L).

The most common decontamination methods and the expected leach-back percentages are as follows:

- on line to a mobile chemical treatment unit in either an energized mode or de-energized mode with an expected leach back of 3–5%;
- hot retrofill (flush) with 1.5 volumes of hot mineral oil with expected leach back of 5%;
- cold retrofill (flush) with one volume of clean mineral oil performed three times with an expected leach back of 10%; and
- cold retrofill with one volume of clean mineral oil with an expected leach back of 15%.

Retrofilling is a term used in the PCB service industry to describe the operation of draining contaminated transformer fluid from a transformer and refilling it with clean fluid. Retrofilling is performed under controlled conditions to prevent damage to the transformer and to remove PCBs efficiently.

A more detailed description of the decontamination technology and methods is found in Appendix C.

All the decontamination methods described above are suitable for transformers with initial PCB concentrations of <1000 ppm. As the initial concentration increases over 1000 ppm, it becomes less and less likely that a single application of any of the above methods will result in PCB concentrations of <50 ppm after 90 days. Multiple application (spaced several months apart) of the decontamination methods will be required, although this can become prohibitively expensive compared to replacing the transformers.

2.3.2 Decontamination Options

Utilities with a large number of mineral oil transformers have been conducting in-house transformer testing and retrofilling programs. Other transformer owners usually hire one of the PCB-management service companies, which also provide mobile chemical treatment, such as PPM Canada, Rondar, Sanexen International, and ENSR Operations. These companies will usually provide a 90-day test warranty for their decontamination work.

The variety of decontamination options available and the even greater variety of owner situations make the selection of options complex. Figure 1 is a simplified flowchart that can be used as a guide to decide which decontamination options are

suitable for different types of transformers. It does not take into account such factors as the number of transformers, transformer maintenance and replacement schedules, geographic location, site access, and municipal and provincial regulations. It also assumes the owner has a sufficient number of transformers, e.g., the flowchart may be of limited use to owners with one or two small transformers. The use of the flowchart requires that many of the decisions be based on economics. The many variables involved ultimately dictate the site- or case-specific costs. However, general ranges of cost are used in the PCB service industry or have been developed by large utilities.

Large numbers (thousands) of mineral oil transformers with low levels of contamination can be tested and retrofilled for approximately $2.00–$3.00/L. The cost for small numbers can range from $5.00 to $10.00/L. Pole-mounted transformers, because of the difficulty of access and their small size, are more expensive to decontaminate on a per-litre basis than ground-mounted transformers. Owners with large numbers of pole-mounted transformers in their inventories will find that the cost of testing and retrofilling can be as much as double these prices. These costs include the cost of chemical treatment of the PCBs in the contaminated oil.

For owners with few mineral oil transformers, the best option may be to contact one of the companies offering testing and retrofilling services.

Costs for decontamination of mineral oil transformers contaminated with PCBs at >1000 ppm may be double or triple because one treatment will likely not reduce the concentration to <50 ppm after 90 days.

For owners with many mineral oil transformers, the highly contaminated mineral oil originally drained off could be mixed (where regulations allow) with mineral oil containing lower PCB concentrations (to reduce the overall PCB concentration, if necessary) and batch-treated using mobile chemical treatment facilities.

Owners with only a few highly contaminated mineral oil transformers can follow the same approach as the large generator if they have the required minimum 10 000 L of contaminated mineral oil to treat, or they can cooperate with other generators (Section 2.2).

2.4 In-service Askarel Transformers

Approximately 7000 askarel transformers are in service in Canada.

2.4.1 Decontamination Technologies

Because of leach-back (discussed in Section 2.3), it is very difficult and costly to decontaminate askarel transformers using the retrofill procedures that have proven successful for contaminated mineral oil transformers. For this reason, other methods have been developed and used in the United States and, to a limited extent, in Canada to decontaminate in-service askarel transformers.

Basically these methods all involve the replacement of the original askarel fluids with a special PCB-leaching fluid. Over a period of several months, with the transformer in use, the fluid is either replaced with clean fluid several times to remove the PCBs or a small distillation unit is attached to the transformer, which continuously removes the PCBs from the leaching fluid.

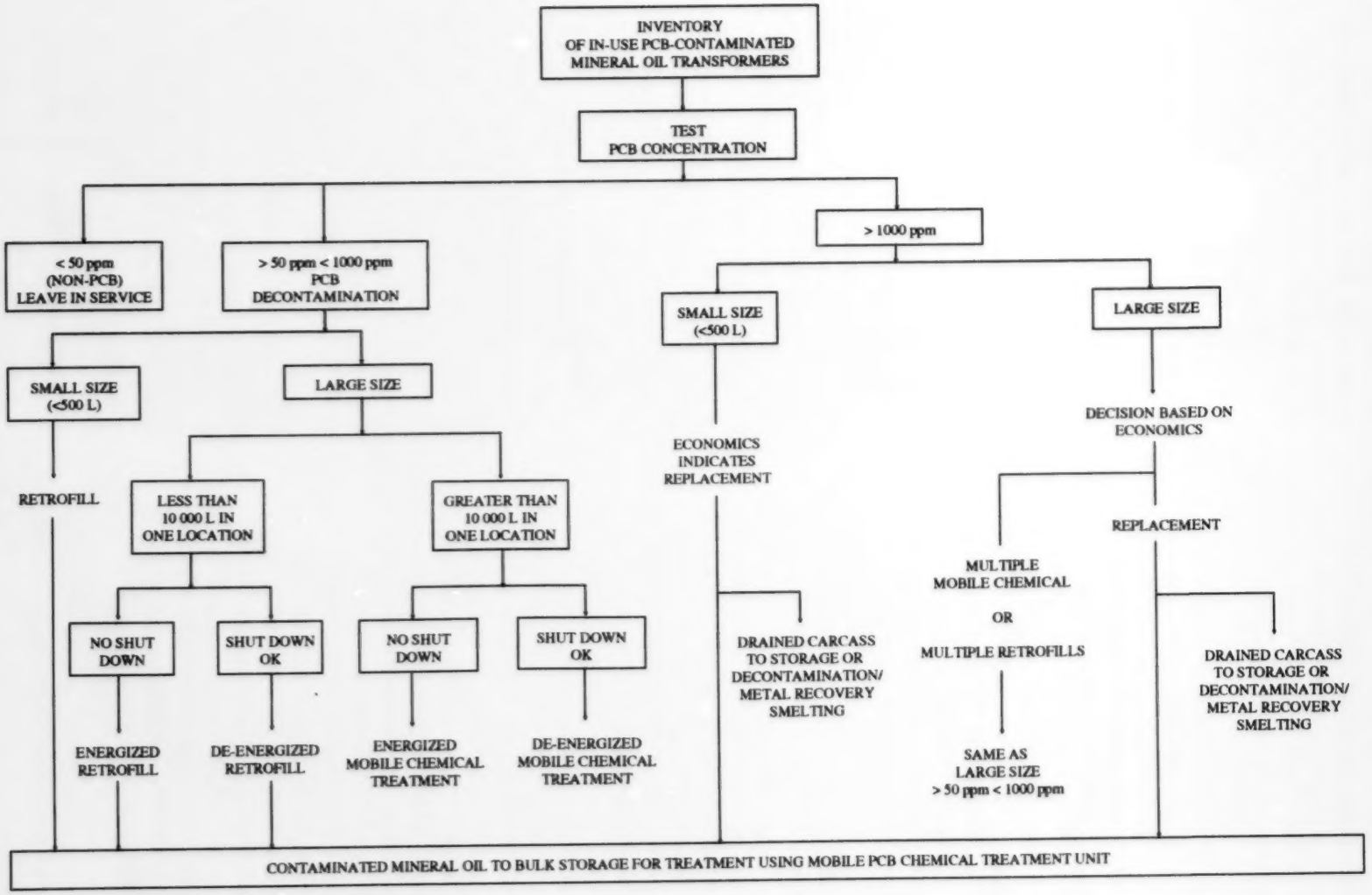

Figure 1 Flowchart for Mineral Oil Transformer Decontamination Alternatives

Two companies in Canada, ENSR Operations and Westinghouse Electric Corporation, offer a decontamination process for in-service askarel transformers.

In ENSR Operations' process, called System 50, the transformer is evaluated to determine its suitability for decontamination and its potential service life. If suitable for decontamination, the following steps are taken:

a) De-energize the transformer, drain the PCB fluid, and re-gasket the transformer.

b) Refill the transformer with System 50 fluid and re-energize it.

c) Attach the System 50 processor to the transformer; the processor removes PCBs from the System 50 fluid over three to six months as PCBs are leached from the transformer interior.

d) Store recovered PCBs on owner's property for eventual incineration.

e) Remove the System 50 processor.

f) Test PCB levels after 90 days.

The System 50 dielectric fluid, manufactured by the Occidental Chemical Corporation, is highly purified, transformer-grade perchlorethylene. Perchlorethylene is basically a solvent that promotes the leaching of PCBs from the transformer interior. It is readily distilled in the distillation unit attached to the transformer.

ENSR Operations has successfully used this system in western Canada and in the Maritimes.

Westinghouse Electric Corporation has a similar system, called Transform, which uses perchlorethylene as the interim leaching fluid and an attached distillation unit to remove the PCBs. Silicone is normally used as the permanent replacement fluid.

In the United States, Unison Transformer Services operates a somewhat similar process (Reclass 50 process) for the decontamination of askarel transformers. In this process, the PCB oil is drained and an interim fluid is added to the transformer to promote leaching. The interim fluid remains in the transformer at least 3 to 4 months. During the leaching period, the interim fluid is removed from the transformer, the PCBs are removed, and the interim fluid is reintroduced into the transformer for further leaching. Eventually, a permanent dielectric (usually silicone) replaces the interim fluid. Several short power outages are required while the various fluids are exchanged. PCBs can be separated from the interim fluid on site or at solvent recovery facilities. Unison reports that decontamination of transformers that initially contained an average of 600 000 ppm PCBs resulted in levels of 20 ppm or less and that the retrofill process does not harm the transformer.

However, there is recent evidence (Myers and Kelly, 1991) to suggest that 90 days is not a long enough period to wait for PCB concentrations to stabilize, and that some transformers that have tested <50 ppm at 90 days continue to increase to PCB concentrations >50 ppm.

2.4.2 Decontamination Options

The decontamination services described in the previous section for in-service askarel transformers are expensive. This is one of the reasons why at least some of the service companies offer an evaluation of the transformer to determine its suitability for decontamination rather than replacement.

At prices ranging from $25.00 to $33.00/L (including PCB incineration, an option available only in the United States), an owner must weigh the cost of replacement (including disposal of the existing askarel transformer; see Section 2.5) against the cost of decontamination for continued use. The remaining life expectancy of the askarel transformers is a key factor in this decision. Other factors that affect the costs are the number and size of transformers, the geographic location, site access, and local and provincial regulations.

The best way to determine an estimated cost is to contact one or two of the service companies, provide them with details of the inventory and other relevant information, and then request a cost quotation. This cost quotation can then be used to decide whether to decontaminate or replace.

2.5 Waste Transformers

Approximately 4000 askarel and 3000 contaminated mineral oil transformers are in storage in Canada awaiting disposal. Decontaminating in-service askarel transformers is expensive; therefore, the alternative of replacing and scrapping askarel transformers may increase as the Canadian PCB phase-out program is implemented. Since decontamination of low-level PCB-contaminated mineral oil transformers still in service is relatively inexpensive, it is unlikely that the number of mineral oil transformers entering storage for disposal will increase significantly.

2.5.1 Decontamination Technologies

Since a waste transformer is any transformer that contained liquids of >50 ppm PCBs before it was drained for storage or disposal, the decontamination methods discussed in this section are applicable to both drained contaminated mineral oil and drained askarel transformers.

In the United States, there are two regulated methods of disposing of PCB transformers (>500 ppm U.S. designation): landfilling and metal recovery/smelting. For a transformer that contained >500 ppm PCBs to be considered decontaminated for eventual metal recovery/smelting, swab tests from pieces of the transformer must indicate PCB levels ≤1 mg/m^2. This is roughly equivalent to 2 ppm. This level is a policy adopted by the U.S. Environmental Protection Agency (EPA) for transformer decontamination and is the surface decontamination level set out in the U.S. Code of Federal Regulations (40 CFR Part 761.125).

At present, three firms in the United States have EPA permits to operate stationary transformer decontamination processes (for metal recovery/smelting purposes). The firms are Unison, in Ashtabula, Ohio; S.D. Myers, in Akron, Ohio; and National Electric/Aptus, in Coffeyville, Kansas.

The method currently approved in the United States for the decontamination of waste PCB transformers at stationary facilities is basically as follows:

a) Before transportation to the decontamination facility, the residual PCB fluid is drained from the transformer (for eventual disposal by incineration).

b) At the decontamination facility, the drained transformer is given an initial cleaning to reduce worker exposure to PCBs.

c) The unit is dismantled and components such as the transformer tank, lamination, wires, and bushings are separated.

d) The separated components are cleaned with solvent and the solvent is distilled for reuse.

e) PCB liquids and combustible components (mainly wood and paper materials) are shipped to PCB incinerators.

f) After testing, the metal components are smelted for metal recovery.

One Canadian firm, Sanexen International (a division of Sanivan) of Montreal, has askarel transformer decontamination technology, which it has used on a commercial basis in Quebec and Manitoba. The levels set by Environnement Québec in its decontamination guidelines of October 1985 are 1.25 mg/m^2 for Arochlor 1260 and 1254 and 2.5 mg/m^2 for Arochlor 1242. The levels apply only to the transformer casing. To determine if the core of the transformer has been successfully decontaminated, the core of the transformer is sampled and the sample is soaked in solvent to remove residual PCBs. The concentration of PCBs in the sample can then be determined based on the weight ratios of each component of the core. Sanexen International, in conjunction with S.D. Myers, has determined the weight ratios in previous studies. If the core contains ≤50 ppm PCBs, it can be sent for metal recovery/smelting.

Chem-Security (Alberta) is currently conducting research and development work at the Swan Hills facility on transformer decontamination for metal recovery/smelting purposes. Again, the method involves solvent flushing and distillation recovery of the solvent. Negotiations are ongoing with the Waste and Chemical Division of Alberta Environment to establish a method and level to determine transformer decontamination.

Other than the Swan Hills facility, Canada does not have an approved PCB incinerator, which is a key component in these decontamination methods. Before the export of PCB wastes from Canada was banned (August 1990), Sanexen International shipped the PCB liquids and other combustibles generated in its decontamination operations to France for approved incineration.

An alternative to the solvent-flushing methods for decontamination is incineration of shredded transformers. Since stationary PCB incineration facilities are available in Canada only at Swan Hills, this method is not available to the Canadian market outside Alberta. However, transformer incineration was part of two mobile PCB incineration projects in Canada in 1990/91.

After testing for PCBs, the incinerated metal could go to landfill or metal recovery/ smelting, depending on local and provincial regulations. Metal recovery is more difficult when transformers are shredded since shredding mixes the different types of metals, which must be later separated for recovery.

Rotary kiln incinerator operators find that the incineration of metals abrades and erodes the kiln's refractory brick at an increased rate. Therefore, transformers are not preferred feed material.

2.5.2 Decontamination Options

In the United States and, to a limited extent, in Canada, transformer service companies have successfully decontaminated waste PCB transformers for metal recovery/smelting. In Canada, these decontamination technologies could be

widely used if a consistent standard, similar to the U.S. EPA standard, were to be developed and applied. This would encourage transformer service companies to expand their Canadian operations or enter the Canadian market.

In the United States, the decontamination facilities are stationary. In Canada, however, Sanexen International operates its decontamination process as a mobile facility. The inventory of in-storage askarel transformers is significant and will probably grow. However, decontamination of this inventory may not economically merit the establishment of a stationary decontamination facility except in Ontario and/or Quebec. In other areas, mobile versions of this technology may be more suitable. This service will, in all probability, be provided by mobile chemical treatment companies already in the business. Waste PCB transformer decontamination is an obvious additional service to offer clients.

The incineration of the PCB liquids and combustible materials is a key component of this strategy. In Alberta, with the availability of the Swan Hills incinerator, this does not present a problem. In other parts of Canada, the PCB liquids and contaminated combustibles must be stored on the owner's property.

The options for mobile PCB incineration are discussed in Section 2.7. The PCB liquids and combustibles generated by waste transformer decontamination operations must also be accommodated by a mobile incineration strategy.

Until PCB incineration facilities (mobile or stationary) are more readily available in Canada, owners of waste PCB transformers can reduce their storage volume of PCB equipment by contracting one of the transformer service companies offering the waste transformer decontamination service. Owners must first check with their provincial department of environment to ensure that the decontamination methods are approved and that the level of decontamination proposed is achievable and will allow disposal of the metal parts by smelting.

Costs for decontaminating transformers for metal recovery/smelting purposes range from $1.76 to $5.50/kg of (drained) transformer weight.

It is recommended that the Canadian Council of Ministers of the Environment develop a standard for the decontamination/ decommissioning of drained waste PCB transformers that will allow metal recovery and smelting of transformer parts. A standard similar to the one used by the U.S. EPA would facilitate the direct use of U.S. decontamination methods.

The option of shredding transformers and incinerating the shredded parts in mobile PCB incinerators is worth consideration. This option is much more difficult to implement than a mobile decontamination unit based on solvent flushing because of the siting requirements of incinerators. However, if a mobile incinerator is to be located in an area for the destruction of PCB wastes such as askarel and capacitors, it may be economical to include transformers. The cost of shredding and incineration is approximately $2200/t. This compares very favourably with solvent-flushing decontamination costs.

2.6 Capacitors

There are 200 000 capacitors in service and 110 000 capacitors in storage in Canada.

These capacitors generally range from 14 to 91 kg. In addition, 63 million small capacitors are in service in light ballasts, and 620 drums (205-L) of capacitor-containing light ballasts are in storage in Canada. Since almost every electrical capacitor manufactured between 1930 and 1978 contained PCB liquids, it must be assumed that all capacitors contain PCBs unless they have been labelled by the manufacturer as non-PCB.

2.6.1 Decontamination and PCB Destruction Technologies

The U.S. PCB phase-out legislation basically required all large capacitors to be removed from feed, food, and unrestricted access areas by October 1, 1988, and to be disposed of by approved PCB incineration within 1 year of removal. The incineration of these materials has now been mainly completed.

Normally, the capacitors are shredded before being fed into the incinerator. The decontaminated metal parts can be sent either for metal recovery/smelting or to a nonhazardous landfill, whichever is more economical.

Other than the Swan Hills incinerator, there are no stationary PCB incineration facilities in Canada. At Swan Hills, Chem-Security (Alberta) has been incinerating capacitors and light ballasts in the facility's rocking kiln.

Two mobile PCB incinerators in Canada (Smithville, Ontario, and Goose Bay, Labrador) have incinerated shredded capacitors.

2.6.2 Decontamination and PCB Destruction Options

Ontario, Newfoundland, and Alberta, as well as the federal government, have approved only high-temperature incineration for the destruction of the PCBs in capacitors and light ballasts, at least on a project-specific basis. Other than in Alberta, stationary facilities for PCB incineration in Canada are in the planning stage and at least 4 to 5 years from realization. Therefore, the only practical near-term solution is mobile incineration. The strategy for mobile PCB incineration is discussed in detail in Section 2.7.

Until mobile incineration is widely accessible in Canada, secure storage of capacitors and light ballasts is the only option.

2.7 Askarel

In Canada, approximately 13 700 t of askarel are in use in electrical equipment and 6000 t are in storage. This inventory of askarel represents most of the PCBs, on a pure PCB basis, in Canada.

2.7.1 Destruction Technology

High-temperature incineration is the only approved technology for the destruction of PCBs in askarel.

In the United States, a great variety of stationary incineration equipment has been permitted, much of it on an interim basis, to burn liquid hazardous waste, including PCBs. These include cement kilns, industrial furnaces, and high-efficiency boilers. However, a third of the hazardous waste incinerators operating under interim permits are now closing, rather than seeking final permits, which have more stringent and costly requirements (Pirages, 1989). In addition, it is expected that, as the U.S. EPA begins to implement stricter land disposal restrictions and generators attempt to reduce their future liability, dedicated hazardous waste incinerators will become increasingly

popular for disposing of PCBs. In the United States, five companies are operating commercial PCB incinerators approved under the Toxic Substances Control Act (TSCA). These are ENSCO, Rollins, General Electric, Pyrochem/Aptus, and SCA Chemical Services.

The mobile incinerator market in the United States was established mainly in response to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA—commonly known as Superfund), which funds the cleanup of many hazardous waste sites in the United States. The technologies developed are mainly directed towards treating contaminated soils and sludges, but some technologies, such as rotary kilns, can be used to treat a wider variety of materials, including liquids. Because stationary incineration facilities have had an adequate capacity to burn PCBs, mobile technologies have not played a significant role in the U.S. PCB phase-out program. However, with the changes in environmental standards for fixed facilities expected soon, the role of mobile facilities may be expanded beyond site remediation.

The use of U.S. mobile incineration technology in Canada is a logical option for the destruction of Canada's inventory of askarel.

The first transportable hazardous waste incinerator in the United States was built under a research and development contract to the Environmental Protection Agency and involved a series of design and construction contractors. This effort began in 1978 and continued until 1985. The unit has since been successfully tested burning PCB liquids (askarel) and has been operated by private companies under contract to the EPA at various government-funded hazardous waste cleanup sites. The unit uses rotary kiln technology.

A number of companies have since developed mobile/transportable PCB incinerators. The ENSCO MWP-2000 mobile rotary kiln was the first mobile incinerator to receive nationwide EPA approval under the TSCA in 1988 to burn PCBs commercially. Since that time, Roy F. Weston's rotary kiln, O.H. Materials Corporation's modified Shirco infrared incinerator, and Ogden Environmental Services' circulating bed combustor have all received nationwide EPA permits under the TSCA to burn PCBs commercially. Also permitted, but not in use, are two Pyrotech MWP-75, liquids-only incinerators owned by ENSCO.

Canada has experience with two mobile PCB incineration systems. In 1990 at Goose Bay, Labrador, O.H. Materials Corporation's modified Shirco transportable infrared PCB incinerator incinerated a Department of National Defence stockpile of 3500 t of PCB-contaminated soils, metals, and askarels. At Smithville, Ontario, ENSCO is currently incinerating 8500 t of PCB-contaminated soils, metals, and askarel for the Ontario Ministry of Environment.

Ontario (Regulation 148/86), Newfoundland/Labrador (Regulation 102/89), and the federal government (Federal Mobile PCB Treatment and Destruction Regulations) have passed regulations dealing with mobile PCB incineration.

2.7.2 Destruction Options

As mentioned in previous sections, the only stationary PCB incinerator in Canada is available for Alberta wastes only; other stationary PCB incinerators are in the planning stage, and are at least 4 to 5 years

from realization; and the border is closed for access to U.S. stationary incinerators. Therefore, mobile PCB incineration is the most viable solution for destroying Canada's askarel inventory.

The mobile incinerators developed in the United States were designed primarily for site remediation work (soil incineration) and, therefore, are not necessarily well suited for liquid PCB incineration. However, the rotary kiln technology is adaptable to incinerating a variety of wastes, including liquids, as a separate feed stream. Technically, and legally under present permits, askarel can be incinerated in either or both the rotary kiln and its secondary combustion chamber. Technically, askarel can also be incinerated in the secondary combustion chamber of the infrared incinerator and the combustion chamber of the circulating bed combustor.

Three options for incinerating askarel liquids are as follows:

a) select a few sites to service large areas,

b) select numerous sites to service relatively small, local areas, or

c) select some combination of the above.

Although these options refer only to askarel incineration, other PCB wastes can and, in some cases, must also be incinerated. As mentioned in Section 2.6, incineration is the only approved method for destruction of capacitors and light ballasts. PCB-contaminated equipment, soils, sludges, solvents, and other materials can also be incinerated at mobile incinerator sites.

The first option listed above would economically favour the use of large transportable incinerators such as the ENSCO MWP-2000, and the second option would economically favour a small mobile incinerator such as the Vesta 80, 100, or 200.

The ENSCO MWP-2000 can be operated economically (i.e., competitive with smaller units) at sites where at least 1500– 2000 t of askarel are to be destroyed for a total burn period of 3 to 4 months (80% operational factor) and a total on-site period of 6 to 7 months. The Vesta 100 and 200 incinerators could be operated economically at sites with significantly smaller quantities of askarel. However, these systems have not yet been fully tested and approved for the destruction of PCBs.

No single industry or utility generator of askarel in Canada is large enough to support the on-site use of equipment the size of the ENSCO MWP-2000. Equipment of this size could be used to service many askarel generators in geographical areas with high concentrations of askarel, e.g., Ontario and Quebec. The incineration of other PCB-contaminated materials at these sites would help lower the per unit incineration costs.

Smaller equipment such as the Vesta 100 or 200 could be economical for the large generators of askarel and other PCB material on an individual basis or at regional sites in areas of Canada with smaller inventories of askarel.

The cost for incineration of askarel in the above-noted minimum quantities ranges from approximately $1500 to $2500/t ($2.00–$3.00/L).

The high priority that the destruction of these liquids should be given and the difficulty in siting the incinerators may make it appropriate for the federal government to take a lead role in providing regional sites. The close cooperation of provincial and municipal governments will be required.

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Appendix A

Canadian Stationary PCB Destruction Facilities

A.1 Background

Only existing Canadian facilities or Canadian facilities well advanced in their planning were considered for evaluation in this report. In Canada, only the Alberta Special Waste Treatment Centre at Swan Hills, Alberta, is operational and commercial.

The Ontario Waste Management Corporation's (OWMC) facility, planned for a location near Bismarck in southern Ontario, is in the advanced planning stage. Although this facility does not meet the criteria of commercial or near-commercial, it was included for information purposes because of its potential impact on Canada's PCB destruction strategy.

British Columbia has made some initial plans for a hazardous waste facility. PPM Canada has a stationary chemical treatment facility in Saskatchewan for PCB-contaminated mineral oil using the same treatment technology as its mobile units.

A.2 Alberta Special Waste Treatment Centre

The Alberta Special Waste Treatment Centre, located at Swan Hills, Alberta, approximately 200 km northwest of Edmonton, is a joint venture between the Alberta Special Waste Management Corporation (ASWMC) and Chem-Security (Alberta), which is owned by Bovar. Chem-Security built the facility and operates it on a contractual basis for the joint-venture partnership. The facility officially opened in September 1987 and after regulatory testing, was licensed by the Alberta government for commercial operation in October 1988.

The treatment system is fully integrated, starting with a collection system that includes two transfer stations connected with the treatment centre at Swan Hills by means of a transportation system using specially designed trucks.

The Centre includes the following units: incinerator, physical/chemical treatment plant, stabilization plant, secure landfill, deep injection well, and waste receiving/storage area. It was designed to treat waste at a rate of 12 500 t of organic waste, 2500 t of inorganic waste, and 2500 t of other waste per year. The following description of the facility deals only with those components treating PCBs.

The incineration facility consists of two Von Roll rocking kilns, each capable of treating approximately 5000 t of organic waste per year. The rocking kiln, rather than rotary kiln, was selected for its ability to incinerate whole 205-L drums of waste without any pretreatment.

The pollution control train was supplied by G.C. Ceilcote, of Ohio, and has proven itself capable of reducing emissions to levels well below those specified in the facility's operating permit issued by the Alberta Department of Environment.

The kilns are used to incinerate both high-level and low-level PCB liquids. On arrival, transformers are drained and then solvent-flushed, with all resulting liquids

incinerated. The cleaned transformers are put in storage. A thermal treatment unit is currently under construction for the decontamination of transformers for recycling.

In 1990, a rotary kiln incinerator was added to the facility to treat bulk solids and sludges.

A.3 Ontario Waste Management Corporation (OWMC)

The Ontario Waste Management Corporation, formed in 1981 by the Ontario government, is proposing to construct and operate a stationary waste treatment and disposal facility near the town of Bismarck in the Township of West Lincoln in the Regional Municipality of Niagara. The total area of land required for the facility is approximately 124 ha, and OWMC is seeking approval through the Ontario Environmental Assessment Act for the treatment and disposal of up to 300 000 t of waste per year.

The disposal facility will consist of the following:

- two identical rotary kilns, each with a waste feed rate of up to 40 000 t per year,
- a physical/chemical waste treatment facility with a capacity of up to 240 000 t per year,
- a solidification plant,
- a secure landfill area, and
- various other facilities including storage buildings and tanks, laboratory, offices, and ancillary services.

Each rotary kiln system will be capable of accepting liquids, sludges, solids, and bulk solid wastes. The primary combustion chamber will operate at a temperature of 1000°C with a gas residence time greater than two seconds. The system will include a waste heat recovery boiler and a flue gas treatment system comprising a three-stage scrubber. The facility will be capable of treating PCBs. The entire development is in the engineering design stage and, based on experience at a facility in West Germany, a Von Roll rotary kiln is proposed.

If the OWMC project receives final approval from the Ontario government, the anticipated start of commercial operation is 1995–1996.

Appendix B

U.S. PCB Phase-out Program and Disposal Options

B.1 PCB Phase-out Program

Since most of the technology in use in Canada or proposed for the future was designed in the United States, it is useful to look briefly at the U.S. PCB phase-out program and the approved PCB treatment/destruction options that have made it successful.

The U.S. PCB phase-out plan is summarized below from the Code of Federal Regulations, 40 CFR Part 761.30 (under the Toxic Substances Control Act).

1) As of October 1, 1985, the use and storage for reuse of PCB transformers (>500 ppm) that pose an exposure risk to food or feed is prohibited.

2) As of October 1, 1985, PCB transformers (>500 ppm) with secondary voltages >480 V cannot be installed in or near commercial buildings, and by October 1, 1990, these transformers must be removed from commercial buildings and locations near them.

3) As of October 1, 1990, PCB transformers (>500 ppm) with secondary voltages less <480 V in use in or near commercial buildings must be equipped with electrical protection to avoid transformer failure caused by high currents.

4) As of October 1, 1988, the use of large PCB capacitors (containing >1.36 kg of PCB fluid) is prohibited if they pose an exposure risk to feed or food. They are also prohibited from any use unless they are within a restricted access location.

5) Any PCB material (>50 ppm) entering storage for disposal must be removed from storage and disposed of by an approved method within 1 year of entering storage.

The above summary demonstrates that the U.S. phase-out effort is directed mainly towards PCB transformers containing >500 ppm PCBs and to large capacitors. The storage of PCB materials is limited by law to a maximum of 1 year.

B.2 PCB Disposal Regulations

By law, U.S. PCB generators have regulated disposal options. The following summarizes the disposal regulations in the 40 CFR Part 761.60.

1) Mineral oil containing PCBs at 50–500 ppm must be disposed of using an approved incinerator, chemical waste landfill,* or high-efficiency boiler.

2) PCB liquids at >500 ppm must be destroyed in approved and specially designed incinerators.

3) PCB transformers (>500 ppm) can be incinerated in an approved incinerator or drained, solvent-rinsed (for 18 h), and

* As of September 1988, the landfilling of liquid PCBs (>50 ppm) or solidified PCBs was banned under the 1984 Hazardous and Solid Waste Amendments of the Resource Conservation and Recovery Act (RCRA). However, the Toxic Substances Control Act (TSCA) still allows this practice for stabilized liquids up to 500 ppm.

disposed of in an approved chemical waste landfill.

4) PCB equipment (<500 ppm) for disposal must be drained, but the disposal of the equipment is unregulated.

5) Small capacitors* can be disposed of by nonmanufacturers in municipal solid waste landfills.

6) Large capacitors** containing 500 ppm or more PCBs must be incinerated at an approved incineration facility.

7) Manufacturers must dispose of all capacitors in an approved incinerator.

B.3 U.S. PCB Disposal Options

As identified in the previous section, PCB generators in the United States have numerous options for the disposal of PCBs. The U.S. EPA has not tracked PCB disposal on a continuous basis, so there are no accurate figures on quantities of PCBs destroyed.

Approved (under the TSCA) chemical waste landfills are at the low end of technology for disposing of PCBs. These landfills can accept PCB liquids (after solidification) of not greater than 500 ppm. Drained and flushed PCB transformers (>500 ppm) are also accepted at chemical waste landfills.

The potential liability of the generator in future cleanups of these landfills discourages the use of this disposal method for liquid PCBs. In 1985, two-thirds of all landfill owners receiving hazardous wastes chose to close their facilities rather than meet stringent groundwater and insurance requirements (Pirages, 1989). As of September 1988, the U.S. EPA did not issue RCRA permits for disposing of liquid (stabilized) PCBs in landfills. Several service companies offer the complete package of flushing (with incineration of liquids) and then disposing of PCB transformers (>500 ppm) in their own landfills.

As an alternative to disposing of solvent-rinsed PCB transformers (>500 ppm) in landfills, the EPA will allow resmelting of the transformer after the transformer has been decontaminated. The decontamination process must pass an EPA TSCA standard of 1 mg/m^2 in the interior of the transformer. Several companies now offer this service using processes that usually involve the draining of the transformer (with PCB liquids sent to incineration), initial solvent flushing, complete dismantling, second solvent flushing of components (and distillation recovery of solvents), testing of flushed components, and then shipment of components for resmelting. PCBs recovered in the distillation process and combustible transformer parts are shipped for incineration.

The chemical treatment of mineral oil transformers by mobile chemical destruction units has been well established since 1978.

In-service askarel transformers can be treated with one of the relatively new reclassification processes such as System 50, Transform, or Reclass 50 (Section 2.4). These processes all involve an interim leaching fluid, and some include a PCB separation (distillation) unit in the

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* "Small capacitor" means a capacitor that contains <1.36 kg of dielectric fluid or, if the weight of dielectric fluid is unknown, a capacitor that has <1639 cm^3 total volume or a capacitor weighing <4.08 kg.

** "Large capacitor" means a capacitor that contains 1.36 kg or more of dielectric fluid.

months to accomplish the desired results and are generally an expensive option suited for large transformers with a relatively long remaining life expectancy.

In the past, a great variety of stationary incineration equipment has been permitted in the United States, much of it on an interim basis, to burn liquid hazardous wastes, including PCBs. These have included cement kilns, industrial furnaces, and high-efficiency boilers for wastes containing <500 ppm PCBs. However, a third of the hazardous waste incinerators operating under interim permits are closing rather than seeking final permits, which have more stringent and costly requirements (Pirages, 1989). In addition, it is expected that as the EPA begins to implement stricter land disposal restrictions (under the RCRA) and generators attempt to substantially reduce their future liability, dedicated hazardous waste incinerators will become increasingly popular for disposing of PCBs. In the United States, five companies are operating dedicated hazardous waste incinerators approved by the EPA under the TSCA.

The mobile incinerator market in the United States was established mainly in response to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA—commonly known as Superfund), which funds the cleanup of many hazardous waste sites in the United States. The technologies developed are mainly based on treating contaminated soils and sludges. However, some technologies, such as rotary kilns, can treat a wide variety of materials, including liquids, as a separate feed material. Because stationary incineration facilities have had an adequate capacity to burn PCBs, mobile technologies have not played a significant role in the U.S. PCB phase-out. However, with the changes in environmental standards for stationary facilities expected soon, the role of mobile facilities may be expanded beyond site remediation.

Appendix C

Mineral Oil Transformer Decontamination Methods

C.1 Chemical Treatment: General Process Details

A chemical treatment project carried out by a contractor usually involves the following basic steps and processes.

- The mobile chemical treatment unit is transported to the client's site in two tractor trailers, one of which contains a mobile laboratory.
- The unit is set up at the location of the transformer or bulk oil storage, and hose connections are made to the transformer or tank.
- Contaminated oil is drawn from the transformer or tank into the mobile unit where it undergoes one of the following treatment processes, depending on the type of destruction unit.
- After a final analysis, the oil is returned to the transformer or a clean tank.

Depending on the process and design of the unit, chemical treatment companies offer the following services.

C.2 Energized Continuous Transformer Mode

The energized continuous transformer mode has advantages to plants and other facilities where electrical shutdown is either expensive or cannot be readily accommodated because it allows the chemical treatment to take place while the transformer is energized (primary voltage of <165 kV).

- The contaminated oil is heated to increase its fluidity and then filtered to remove sludges.
- A reagent is mixed with oil in a ratio determined by on-site laboratory analysis.
- The mixture is injected into a reaction chamber where the chemical destruction of the PCBs occurs.
- The reagent is separated from the decontaminated oil by a centrifuge.
- The decontaminated oil is filtered through fuller's earth and degassified to restore its dielectric properties.
- After a final analysis the oil is returned to the transformer.

C.3 De-energized Retrofill

De-energized retrofill is usually performed when the transformer can be shut down.

- Contaminated mineral oil is drained from the transformer into a dedicated tanker.
- As the contaminated oil is drained, hot, clean oil is added into the top of the transformer (usually from an on-site tanker truck).
- More than one transformer volume of hot oil is often used in the flushing process,

with the drained oil going to the contaminated oil tanker.

This process is often used where a number of transformers are to be decontaminated that are not situated close enough together to facilitate a single setup of the mobile chemical destruction unit.

The decontaminated oil can be reused to decontaminate other transformers, stored onsite for future transformer maintenance work, or sold to an oil reclaimer.

Sometimes nitrogen is used to protect (by oxygen elimination) the internals of the transformer while the drained oil is decontaminated elsewhere.

C.4 Energized Retrofill

- Hot, uncontaminated oil is pumped into the transformer at the same time and rate as the contaminated oil being withdrawn from the transformer.
- Hot oil circulation continues for multiple transformer volumes to achieve the required reduction in PCB concentration and aid in transformer desludging.
- The contaminated oil is pumped into a holding tank.
- Multiple transformers are often serviced in this manner until the contaminated oil tanker is full. It is then moved to the mobile chemical treatment unit for processing.

C.5 Batch Processing of Bulk Oil

- Bulk oil can be batch processed by mixing the reagent with the contaminated oil in the storage tank and leaving it to react until the PCBs are destroyed.
- The oil is then restored in the mobile unit by the centrifuge, filtered, and degassified. It is then ready for reuse.

Appendix D

Commercial and Near-commercial Mobile/Transportable PCB Incinerators

D.1 ENSCO MWP-2000 Mobile Incinerator

D.1.1 Background

In 1981, a commercial transportable incinerator was designed and built by Pyrotech Systems featuring a liquid injection combustor using an oxygen-enriched burner for PCB incineration. This unit, the MWP-75, is rated at 10.55 million kilojoules per hour and received permits in 1982 for incineration of liquid PCBs from several regions of the U.S. EPA. ENSCO purchased Pyrotech in 1982. The design of the larger MWP-2000 incinerator began in early 1983.

ENSCO, of Little Rock, Arkansas, was the first hazardous waste treatment firm to commit resources to the development of transportable incinerators. It has now completed the construction and testing of three MWP-2000 incinerators. Design of the MWP-2000 incinerator drew heavily upon ENSCO's experience with the design and operation (since 1976) of a large stationary commercial hazardous waste incinerator in El Dorado, Arkansas. This incinerator is designed to burn liquids, solids (soils, metals, etc.), and sludges. ENSCO received its nationwide EPA TSCA permit for the MWP-2000 in March 1988.

In October 1988, ENSCO was awarded a contract by the Ontario Ministry of Environment to incinerate approximately 8500 t of PCB-contaminated liquids, equipment, and soil at a former PCB transfer/storage site in Smithville, Ontario. However, in January 1989, ENSCO issued a press release announcing a corporate restructuring due to financial losses in its site remediation business. ENSCO is not currently pursuing new work in the mobile incineration area and is actively seeking purchasers for its mobile incineration equipment.

D.1.2 Design Features

The MWP-2000 is constructed in modules and is designed to be transported over U.S. highways. The layout of the incinerator is shown in Figure D.1. There are four basic processing trailers: solid waste incineration, secondary combustion (liquid incineration), energy recovery, and air pollution control. Additional trailers include a central control room, laboratory, material handling conveyers, a water treatment unit for the boiler and process effluents, a decontamination and shower trailer, and others, totalling about 12 trailers at a complete site. Setup of the equipment onsite takes approximately 4 to 5 weeks.

Solids processing takes place in a 1.68-m internal diameter by 9.14-m-long rotary kiln incinerator. The rotary kiln is arranged with a 14.8-million kJ/h burner in the firing face on the upstream end of the kiln. Solid waste is also fed through the front firing face, resulting in a concurrent flow of solids and burner gases. The kiln is brick-lined and operates between 760 and 1193°C. Feed rates to the kiln have ranged from 959 kg/h for wastes with high heating value to 4818 kg/h for contaminated soils. Retention time of the solid waste in the kiln is about

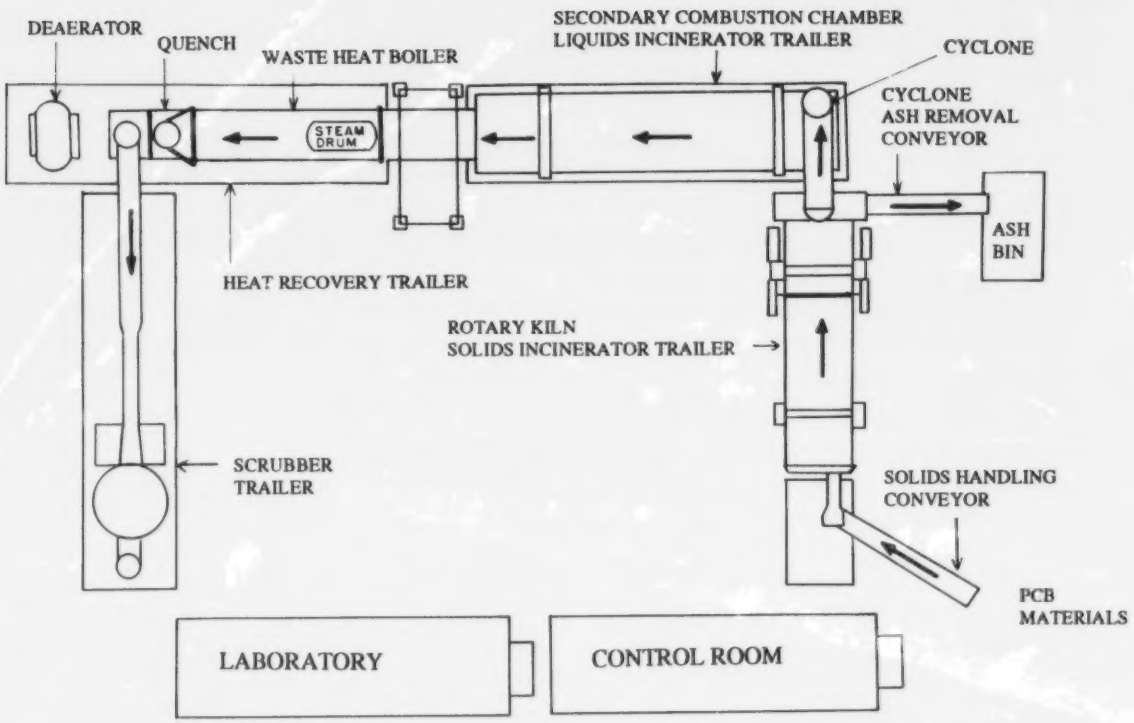

Figure D.1 Typical MWP-2000 Equipment Arrangement

40 minutes with normal kiln slope and rotational velocity.

A dual parallel cyclone arrangement for particulate removal is located immediately downstream from the rotary kiln. The cyclones employ a double vortex design and are refractory lined. The rated efficiency of the cyclones is 99%.

The secondary combustor is sized to incinerate 909 kg of PCB liquids per hour with an average HHV (higher heating value) of 23 260 kJ/kg. The secondary combustor also provides a minimum of 2.0 seconds gas residence time at 1200°C in the base design case.

Acid gas removal is accomplished using a two-stage scrubbing arrangement. The first scrubbing stage consists of a water quench, which removes up to 80% of the hydrogen chloride from the combustion gases. High-efficiency scrubbing is accomplished in a second stage, which consists of a counterflow packed tower with high recirculation rates. The packed tower removes 99% of incoming hydrogen chloride.

Additional particulate removal is accomplished in a third unit, a jet-eductor scrubber, which also serves as the prime mover for gases from the rotary kiln and secondary combustor. Particulate control has been demonstrated at 45 mg/m^3. The U.S. RCRA standard is 180 mg/m^3.

The control system for the incinerator is located in an electronics trailer, which is set

up near the processing equipment. A microcomputer supervises the operation of the incinerator using software that specifies temperatures, feed rates, residence time, emissions limits, and other key operating parameters. An automatic waste shut-off sequence is enabled by the microcomputer if specified operating conditions are not met. The incinerator control room operator has complete control of the system, including motor starters, from the operating panel.

D.1.3 TSCA Permit Feedstock Restrictions

ENSCO received its nationwide U.S. EPA TSCA permit in 1988. The conditions of approval shown in Table D.1 are part of that permit.

D.2 O.H. Materials Corporation Mobile Infrared Incinerator

D.2.1 Background

O.H. Materials Corporation (OHM), with headquarters in Findlay, Ohio, is an integrated environmental services company specializing in turn-key projects.

OHM purchased a transportable infrared incinerator designed and built by Shirco Infrared Systems of Dallas, Texas, in 1986. In 1986, OHM began using the incinerator at a Florida Superfund site, where it incinerated over 18 000 t of PCB-contaminated soil. Throughout the project, OHM made important design and operating modifications to the Shirco unit, to the extent that it is now referred to as a "modified" Shirco unit.

D.2.2 Design Features

The OHM mobile infrared incinerator was designed to be transported to any location in the continental United States accessible by road. The incineration components are mounted on seven large trailer units, with several units requiring special permits because of their oversize dimensions. Setup onsite is accomplished in approximately 3 to 4 weeks.

The overall incineration unit consists of a waste preparation system and weigh hopper, infrared primary combustion chamber, supplemental propane-fired secondary combustion chamber, venturi/scrubber,

Table D.1 TSCA Permit Conditions for ENSCO MWP-2000

Feedstock*	Maximum PCB Level	Maximum Feed Rate	Method of Treatment
1) Soil	1.9%	546 kg/h**	kiln
2) Waste fuels	23%	132 kg/h	kiln
3) PCB liquids	42%	784 kg/h	secondary combustor with kiln feed
4) PCB liquids	43%	959 kg/h	secondary combustor with no kiln feed
5) PCBs shall be processed at a rate not to exceed 409 kg/h of pure PCBs.			

* At Smithville, up to 1818 kg/h of 1.9% PCB soil or up to 4818 kg/h of 0.58% PCB soil is permitted. PCB liquid feedrates permitted at Smithville are similar to U.S. EPA.

** Initial testing was at 546 kg/h; however, successful testing was subsequently done at 1818 kg/h.

exhaust system, and data collection and control systems, all mounted on trailers. The system process flow and the overall test site layout are presented schematically in Figure D.2.

Solid waste feed material is processed by waste preparation equipment designed to reduce the waste to the consistency and particle sizes that can be processed by the incinerator. After transfer from the waste preparation equipment, the solid waste feed is weighed and conveyed to a hopper mounted over the furnace conveyor belt. The feed hopper screw rate and the conveyor belt speed rate are used to control the feed rate and bed depth.

The incinerator conveyor, a tightly woven wire belt, moves the solid waste feed material through the primary combustion chamber where it is brought to operating temperature (982°C) by infrared heating elements. Rotary rakes or cakebreakers gently stir the material to ensure adequate mixing, exposure to the chamber environment, and complete combustion. When the incinerated feed (ash) reaches the discharge end of the incinerator, it is cooled with a water spray and discharged by a screw auger/conveyor to an ash hopper.

The combustion air is supplied to the incinerator through a series of overfire air ports at various locations along the incinerator chamber and flows countercurrent to the conveyed waste feed material.

Exhaust gas exits the primary combustion chamber into the secondary combustion chamber where propane-fired burners burn any residual organics present in the exhaust gas. The secondary combustion chamber burners are set at a predetermined temperature (1204°C). Secondary air is supplied to ensure adequate excess oxygen levels for complete combustion. Exhaust gas from the secondary combustion chamber is quenched (to 82°C) by a water-fed venturi/scrubber to remove particulate matter and acid gases and then transferred to the exhaust stack by an induced draft fan where the gas is discharged to the atmosphere.

The controls for the main unit and the data collection indicators, which make up the data collection and control system, are housed in a specially designed van.

D.2.3 TSCA Permit Feedstock Restrictions

OHM received its nationwide U.S. EPA TSCA permit in December 1988. In general, the permit allows the incinerator to be used to destroy PCB liquids and PCB-contaminated soils or debris under the conditions shown in Table D.2.

Table D.2 TSCA Permit Conditions for the OHM Incinerator

Feedstock	PCB Level	Feed Rate
1) Soil	5600 ppm max.	6272 kg/h max.
2) Liquids	60% max.	premixed with soil to maximum concentration in 3)
3) Soil	20 000 ppm max.	5227 kg/h max.

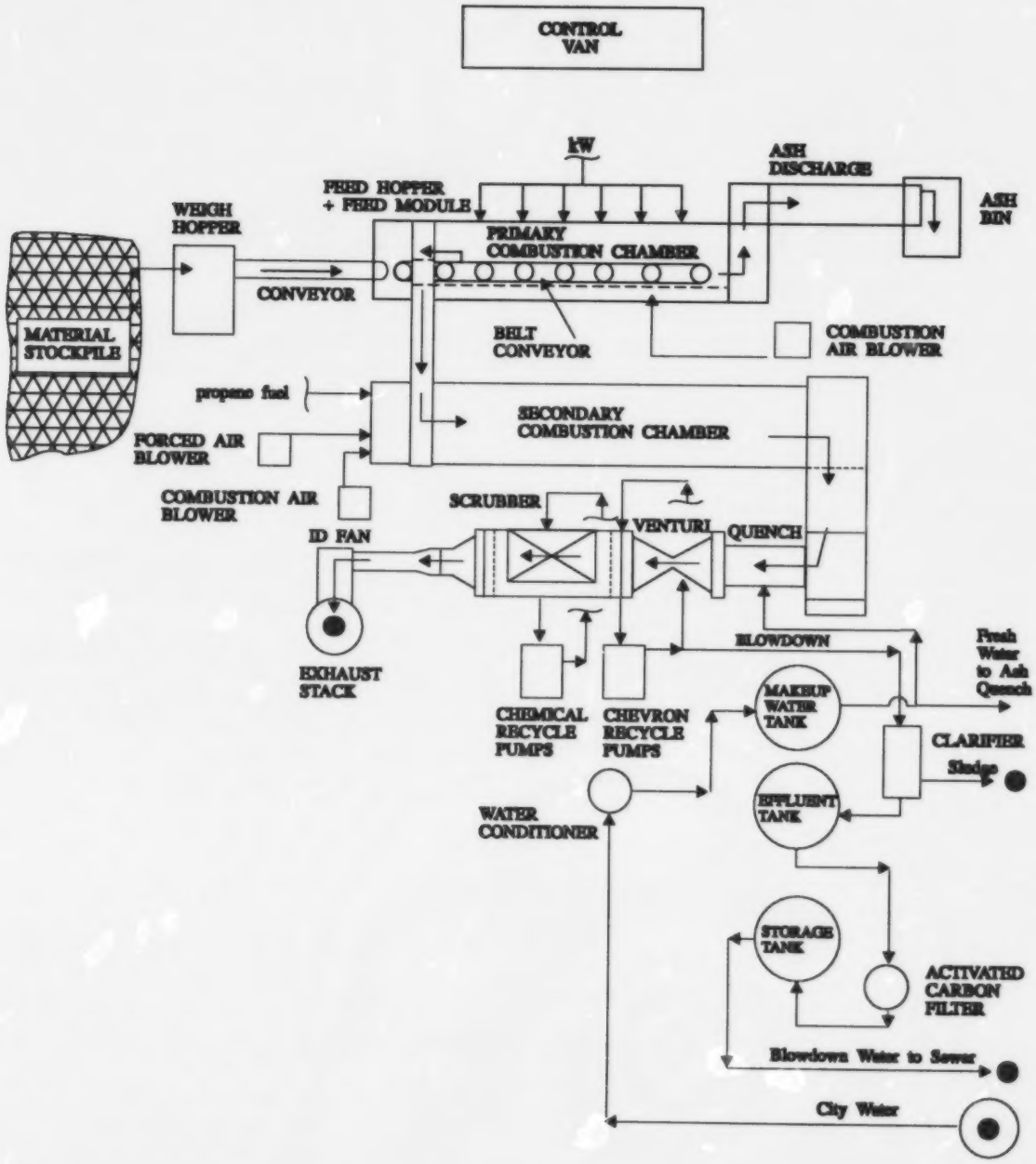

Figure D.2 Typical Infrared Incinerator Setup

Other conditions include the following:

- Debris such as lumber and plastic bags can be mixed with soil at a level not to exceed 5%.
- Chloride content of soil is limited to 0.9%.
- A Paint Filter Liquids Test (EPA Method 9095) must be performed on the soil and liquid mixture.

D.3 Roy F. Weston Transportable Incineration System

D.3.1 Background

Roy F. Weston, Inc., of West Chester, Pennsylvania, designed its transportable incineration system (TIS) to treat soils contaminated with PCBs. In 1988, while conducting the cleanup of approximately 6818 t of PCB-contaminated soil at the Lauder Salvage Yard site in Illinois for the Illinois EPA, the company performed federal EPA-monitored demonstration burns. Weston was granted a nationwide EPA TSCA permit in October 1988.

D.3.2 Design Features

The design and fabrication of the Weston transportable incineration system were based on the requirement that the system be transportable, i.e., that the system could be disassembled into a reasonable number of modular sections and relocated and reassembled at a different site. Most modules are skid-mounted and placed on constructed foundation pads during the setup period of approximately 6 weeks. Classified soil (i.e., <0.79 cm in diameter) is introduced to the solid waste feed system by a front-end loader. The solid waste feed system consists of the following components:

- dump hopper/withdrawal screws,
- cross drag conveyor, and
- feed screws.

The solid waste feed system is designed to accommodate 5455 kg/h of soil (wet basis).

The rotary kiln is designed to provide a minimum of 30 minutes soil retention time. The kiln is designed to dry and heat the feed material to 982°C. The heated ash discharging the rotary kiln is cooled with conditioning water sprays to 149°C and deposited into watertight dumpsters.

Exhaust gases from the rotary kiln pass through a secondary combustion chamber. The chamber is designed to provide a minimum of 2 seconds gas retention time. Natural gas or propane is used to heat gases in the secondary combustion chamber to a minimum temperature of 1149°C.

Overhead gases from the secondary combustion chamber are cooled to 538°C by a water spray in the spray tower. There is an option to add sodium hydroxide (NaOH) to the water in the spray tower to neutralize acidic gases (i.e., hydrochloric acid [HCl] to sodium chloride [NaCl]). Particulate (and NaCl) fallout is directed by a screw conveyor to the ash collection system.

Discharge gases from the spray tower are directed through two heat exchangers that operate in series to reduce the temperature of the flue gas to approximately 269°C. Particulate fallout is conveyed to the ash collection system.

Exhaust gases enter the baghouse for particulate removal. The baghouse is designed to handle 623 m^3/min of flue gas. The maximum emission level is 180 mg/m^3 (corrected to 12% carbon dioxide). The baghouse is of the jet pulse design, i.e., high-pressure air periodically pulses to

remove particulate that has accumulated on the bags. Particulate is conveyed out of the baghouse hopper and directed to the ash collection system. Gases from the baghouse are directed to the scrubber for acid gas control.

The flue gas is scrubbed with a caustic solution for neutralizing the acidic gas component (HCl). The scrubber liquor (i.e., water and salts generated upon combination of acid and caustic) is collected for onsite treatment and reuse. Scrubber blowdown water is filtered and used as system makeup water for ash cooling and dust control. Scrubber gases are directed to the stack for atmospheric discharge.

D.3.3 TSCA Permit Feedstock Restrictions

Weston received its TSCA permit in October 1988. In general, the permit allows the incinerator to be used to destroy PCB-contaminated soils and liquids under the conditions shown in Table D.3.

The addition of the liquid PCBs to the soil must result in PCB concentrations in the soil of not more than 12 200 ppm.

D.4 Ogden Environmental Services Circulating Bed Combustor

D.4.1 Background

Ogden Environmental Services (OES), headquartered in San Diego, California, is part of the Ogden Corporation. Ogden has been in the incineration business for many years through its division of Ogden Martin, which designs energy-from-waste incinerators for municipal solid waste disposal. OES was formed in 1986 to provide toxic and hazardous waste management services. The circulating bed combustor (CBC) technology and 41-cm CBC pilot plant were purchased in 1986 from GA Technologies. The 41-cm pilot plant has a permit under the U.S. TSCA.

In 1988 OES was awarded a contract to incinerate over 70 000 t of PCB-contaminated soil at an oil field site in Swanson River, Alaska. During this cleanup project, EPA-monitored test burns were conducted and a TSCA nationwide permit for a 91-cm transportable CBC facility was granted in June 1989. OES has built three 91-cm CBC facilities.

D.4.2 Design Features

Conventional technologies for the thermal destruction of wastes (including liquid injection incinerators, rotary kilns, fixed single and multiple hearths, and conventional fluidized beds) are often faced with operation at high temperatures with relatively low throughputs and must use afterburners and scrubbers to satisfy regulatory requirements. OES developed an advanced thermal waste treatment system using a new generation of combustion technology called the circulating bed combustor. The CBC uses high turbulence

Table D.3 TSCA Permit Conditions for Weston Incinerator

Feedstock	Maximum PCB Level	Maximum Feed Rate
1) Soils	12 200 ppm	6 318 kg/h
2) Liquids	57.3%	91 L/h (sprayed onto the soil in 1)

and lower temperatures, but obtains the same or greater destruction efficiencies as high-temperature processes. This results in relatively higher throughputs at a lower thermal rating, eliminating the need for afterburners or scrubbers. The unit satisfies air quality control standards and eliminates secondary waste streams.

The transportable CBC has a nominal capacity of 70 to 98 t of contaminated soil per day, but can be higher or lower, depending on the moisture and energy content of the specific soil feed stream. The unit is completely self-contained (including soil feed systems and ash removal systems) and is transportable by truck, rail or barge. It requires the equivalent of 16–18 legal-weight tractor-semitrailer shipments. Setup time on site is approximately 10–11 weeks.

The CBC is designed to operate at ambient temperatures ranging from -28°C to +43°C, permitting operation in arctic to desert environments, and has a relatively small footprint, allowing installation in tight working spaces. The system operates at subatmospheric pressure so that leakage will not result in escape of hazardous materials. Utility requirements average about 250 kW electrical power and natural gas, propane, diesel fuel, or other available auxiliary fuel. The only water requirements are for personnel needs and decontamination.

The CBC is an advanced fluidized-bed combustor that uses high-velocity air to retain circulating solids in a highly turbulent combustion loop. The configuration of a typical CBC system is shown schematically in Figure D.3. The combustion chamber is 9 m high and has a 31-cm-thick ceramic liner. Solid feed stock is introduced into the combustor loop at the loop seal where it immediately contacts the hot recirculating solids stream exiting the cyclone. Liquid feeds are typically injected directly into the combustion zone of the CBC. Upon entering the CBC, hazardous materials are rapidly heated and continue to be exposed to operating temperatures from 788°C to 871°C throughout their residence time. Residence times in the combustor range from 2 seconds for gases to 30 minutes for larger feed materials (2.54 cm). The high-combustion-air velocity and circulating solids create a uniform temperature (±28°C) around the combustion loop (combustion chamber, hot cyclone, return leg), resulting in efficient combustion and eliminating the need for an afterburner. This high turbulence allows the unit to perform dry scrubbing in the combustor. During operation, ash is periodically removed from the CBC by means of a water-cooled ash removal system. The hot gas leaving the cyclone is cooled in a flue gas cooler, and particulates escaping the cyclone are collected in fabric filter baghouses.

The transportable CBC consists of seven structural steel modules, which contain the process equipment and provide the structural framework of the CBC. The module frames are fabricated of wide-flange structural beams on jigs that help maintain dimensional tolerances. Because the modules do not exceed 2.6 m wide, 3.2 m high, and 10.7 m long, they can be transported on a single drop trailer without transportation permits. All seven modules are shown installed in Figure D.4.

D.4.3 TSCA Permit Feedstock Restrictions

OES holds two U.S. EPA TSCA permits. Its first permit was granted in March 1986 for the pilot plant 41-cm CBC facility. This permit allows the incineration of PCB-contaminated soils up to 10 000 ppm PCBs. A second permit was granted in

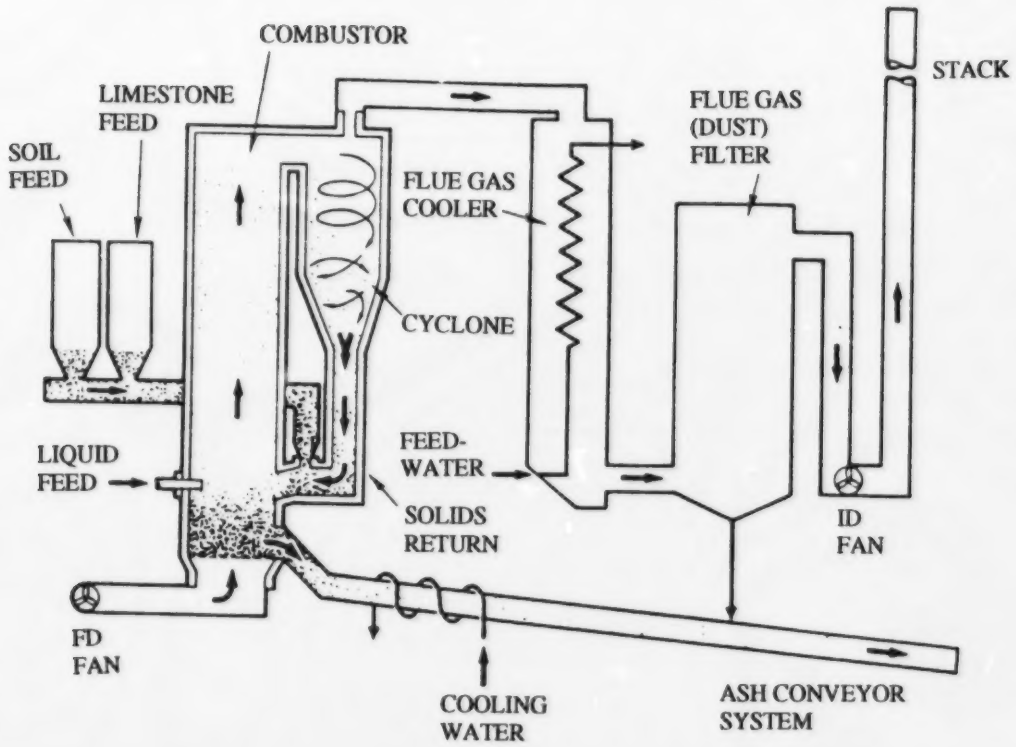

Figure D.3 Circulating Bed Combustor Schematic Diagram (Source: Ogden Environmental Services)

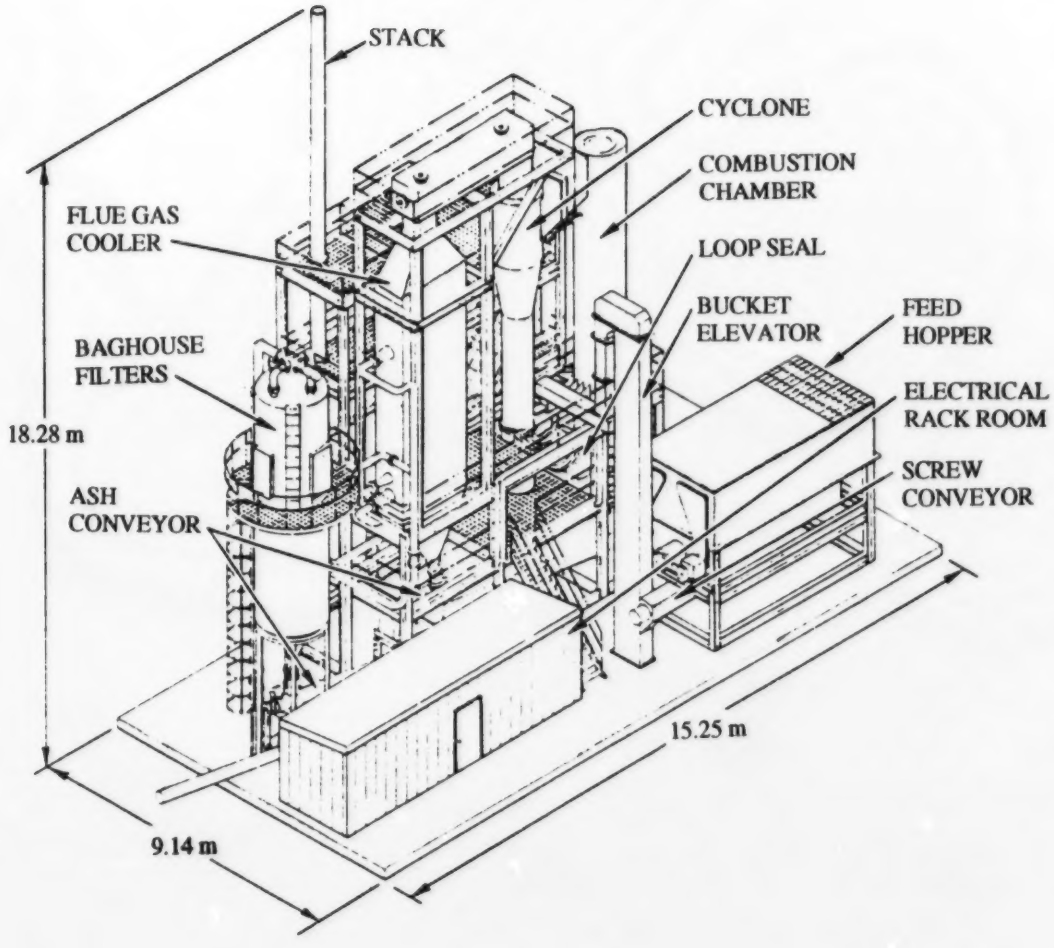

Figure D.4 Circulating Bed Combustion System Installed (Source: Ogden Environmental Services)

June 1989 for the 91-cm commercial size CBC unit. See Table D.4 for conditions.

D.5 Near-commercial Mobile/ Transportable Incinerators

The following companies have made application to the U.S. EPA or other jurisdictions to conduct demonstration test burns of PCBs using mobile/transportable incinerators. These are considered near-commercial technologies.

D.5.1 Vesta Technology Mobile Rotary Kiln

Vesta Technology, of Fort Lauderdale, Florida, was formed in 1986 for the purpose of building and operating mobile hazardous waste incinerators on a national basis. The company's major investor is Attwoods, PLC Corp., of England, a major international solid waste handling corporation. Vesta's mobile units are manufactured by ThermAll Engineering, New Jersey.

The first Vesta unit was constructed in 1986, and since that time units have been used on site cleanups to destroy pesticide, carbon tetrachloride, nitrobenzene, creosote, and dioxin contamination in soils. Vesta does not have a U.S. TSCA permit, however, a PCB test burn program was conducted in Canada in 1990. The results from this program are not yet available.

Vesta's mobile incinerators incorporate the established rotary kiln incinerator design and new, compact scrubber technology. The incinerators are designed to achieve the 99.9999% "destruction removal efficiency" required under the TSCA to destroy PCBs in liquid, solid, or sludge form.

The incinerators are transportable on one or two standard trailers over all state and federal highways, and require a maximum on-site setup time of 24 hours, keeping mobilization charges low.

Vesta has three sizes of mobile incinerators:

- the Vesta 80, an 8 440 000-kJ/h unit, with a processing rate of 455–909 kg/h,
- the Vesta 100, a 10 550 000-kJ/h unit, with a processing rate of 1364–2273 kg/h, depending on the waste, and
- the Vesta 200, a 26 400 000-kJ/h unit, with a processing rate of up to 3600 kg/h.

Vesta can handle large tonnages with several machines, operating in a "multi-unit" configuration, providing the capability of processing 5445–7273 kg/h. This maintains the units' mobility, flexibility, and uncomplicated setup procedure. In the event of a mechanical problem in one unit, the other units continue operation and the risk of lost revenue associated with work stoppages is reduced. The multi-unit configuration

Table D.4 TSCA Permit Conditions for OES Combustor

Feedstock	Maximum PCB Level	Maximum Feed Rate
1) Soils	600 ppm*	4000 kg/h
2) Debris (lumber, rags, clothing) mixed with soil at less than 5% of feed stream.		

* Maximum PCB level available for testing at the Swanson River site.

offers the flexibility to process liquid and solid waste streams simultaneously.

Computers monitor and record all process parameters and supply a dated and timed printout to ensure compliance with federal and state regulations. The monitoring system incorporates a shutdown mechanism for the incineration system should any of the parameters deviate from a range of set points.

Decontamination and demobilization of the unit is accomplished within 3 days.

D.5.2 IT Corporation Hybrid Thermal Treatment System

IT Corporation, of Knoxville, Tennessee, has designed and built a hybrid thermal treatment system (HTTS), composed principally of a rotary kiln and a vertically fired secondary combustion system.

The HTTS is one of the larger transportable units. It is capable of treating an average of 18.2 t/h. The complete HTTS unit fits on 20 tractor trailers. IT Corporation has built three such units.

IT Corporation has used the HTTS units to incinerate soil contaminated with TNT and DNT (dinitrotoluene) at the Cornhusker Army Ammunition Plant in Iowa and at a similar site in Louisiana. A TSCA permit has been granted to conduct PCB trial burns in Texas.

D.5.3 Haztech Transportable Infrared Incinerator

Haztech, of Decatur, Georgia, is owned by Westinghouse Electric Corporation. In 1986, Haztech purchased a transportable infrared incinerator from Shirco Infrared Systems, of Dallas, Texas. The unit was immediately moved to a Superfund site at Peak Oil, Brandon, Florida, where it was used to destroy approximately 7000 t of PCB-contaminated waste oil sludge.

The operation of the Haztech-owned incinerator at the Peak Oil site is the subject of a Superfund Innovative Technology Evaluation (SITE) report (Sept. 1988). The report documents many of the operational problems with the Shirco infrared incinerators.

D.6 Evaluation of Mobile/ Transportable Incinerators

The mobile/transportable incinerators described in the previous sections were designed primarily for the American hazardous waste, site remediation market. Accordingly, most equipment was designed to treat large volumes of contaminated soil.

In the U.S. market, the destruction of PCB liquids and equipment is well served by numerous permitted stationary hazardous waste incineration facilities, industrial boilers, cement kilns, and chemical waste landfills.

Table D.5 summarizes the capabilities of the commercial and near-commercial mobile/ transportable incinerators. Only three are approved for liquids-only incineration. Only the ENSCO MWP-2000 was specifically designed for incinerating PCB equipment (capacitors). Only the Vesta 100 is considered truly mobile. The others are "relocatable" industrial equipment installed for use by removing various modules from the transportation trailers and interconnecting them.

Table D.5 Evaluation of Mobile/Transportable Incinerators

Company/Model	Technology	Designed Waste Feeds	Maximum Designed Throughput	TSCA Permit Feedstock Restrictions	Transportable/Mobile and Trailers Required	On-site Setup Time
ENSCO/ MWP 2000	Rotary kiln & secondary combustion chamber	Liquids Soils Capacitors Waste fuel	909 kg/h 5455 kg/h 909 kg/h —	42% PCB @ 785 kg/h 1.9% PCB @ 546 kg/h — 23% PCB @ 132 kg/h	Transportable, 12 trailers	4–5 wks.
O.H. Materials Corp./Modified Shirco Infrared Incinerator	Infrared primary chamber & secondary combustion chamber	Soils Liquids Liquids w/ soil	NA NA NA	0.56% PCB @ 6273 kg/h 60% PCB w/soil 2.0% PCB @ 5227 kg/h	Transportable, 7 trailers	3–4 wks.
Roy F. Weston/ Transportable Incineration System	Rotary kiln & secondary combustion chamber	Soils Liquids	9091 kg/h —	1.22% PCB @ 6318 kg/h 57.3% PCB @ 91 L/h	Transportable, NA	6 wks.
Ogden Environmental Services/CBC	Circulating bed combustor	Soils Liquids	4091 kg/h 400 kg/h	600 ppm PCB @ 3636 kg/h —	Transportable, 16 trailers	10–11 wks.
Vesta Technology/ Model 80 Model 100 Model 200	Rotary kiln & secondary combustion chamber	Liquids, solids, or sludge	909 kg/h 2273 kg/h 3600 kg/h	— — —	Mobile, 3 trailers Mobile, 4 trailers Mobile, 6 trailers	24 h
IT Corp./HTTS	Rotary kiln & secondary combustion chamber	Liquids, solids, or sludge	18 182 kg/h	—	Transportable, 20 trailers	NA
Haztech/ Shirco Infrared Incinerator	Infrared primary chamber & secondary combustion chamber	Soils Liquids Liquids w/soils	NA NA NA	— — —	Transportable, 7 trailers	3–4 wks.

NA: Information not available

Appendix E

Decontamination Technologies for Waste Transformers

E.1 Decontamination for Smelting

E.1.1 Unison (G. & L. Recovery Systems)

G. & L. Recovery Systems received its U.S. EPA permit in February 1989. Its process consists of the following steps:

- initiation of a tracking system to monitor each PCB transformer throughout the decontamination process;
- draining of all residual dielectric fluid and its containment for eventual disposal by incineration;
- prewash of a drained transformer to reduce the environmental impact and worker hazard of residual PCBs when disassembled;
- disassembly of transformer (i.e., separation into components such as transformer tank, laminations, wire, and bushings) and containment of other solid waste (i.e., paper, cardboard) for disposal;
- solvent wash of separated transformer components at room temperature;
- recovery of reusable solvents;
- disposal of nonreclaimable, unusable parts and removed PCBs by incineration;
- recovery of cleaned metal by smelting; and
- reclaiming cleaned epoxy and ceramic bushings for reuse.

Unison charges customers between $1.32 and $1.76 (U.S.)/kg for the G. & L. Recovery Systems process, not including transportation.

Metals must be cleaned to 10 μg/100 cm^2 (1 mg/m^2) or less before smelting, and bushings (not containing PCB liquids as part of their construction) to 3 μg/100 cm^2 or less prior to reuse. Solvent returned to the primary and secondary washing stations must not contain more than 2 ppm PCBs. The solvent is recovered through a distillation process. The solvent bottoms are incinerated.

Unison is considering entering the Canadian market, but has been reluctant because of the lack of incineration facilities.

E.1.2 S.D. Myers

S.D. Myers received an EPA permit in the spring of 1989. It operates a transformer decontamination facility in Akron, Ohio. The facility is set up to process 45 455 kg/d of equipment. The process involves the same basic steps as the G. & L. Recovery Systems process. Solvents and cleaning methods are proprietary. The plant is operating at full capacity, treating approximately 20 transformers per day. The cost is estimated to be between $1.32 and $1.54 (U.S.)/kg, not including transportation.

The process consists of the following steps:

- flushing the chilled transformer with warm 1,1,1 trichlorethylene (TCE) vapours (vapour condenses on the inside of the transformer and drips out the bottom; the process is complete when only vapour comes out the bottom);
- cooling the transformer again and repeating the flushing process;
- disassembly of the transformer by unbolting the top or cutting it off;
- incineration of the wood and cardboard in a slagging rotary kiln where the ash is vitrified and can be disposed of in an ordinary landfill;
- vapour degreasing of each piece of the transformer; and
- testing then smelting and recovery of the metals.

The TCE is recovered through a distillation process.

The process costs transformer owners about $2.13 (U.S.)/kg, excluding transportation.

The company is owned by Westinghouse Electric Corporation, which may be considering importing the technology to Canada.

E.1.4 Sanexen International

Sanexen International, of Montreal, has offered a transformer decommissioning process in Canada for several years. The process originally started as a liquid-solvent extraction process and then became a vapour-solvent extraction process. Now both liquid- and vapour-solvent extraction processes are used. The vapour extraction tanks are heated and all of the solvents are recovered and distilled. The solvents are proprietary. In some cases, the core of the transformer has to be opened in order to achieve the decontamination levels set by Environnement Québec; in other cases the core is not opened.

Sanexen has treated more than 200 mineral oil transformers and more than 30 askarel transformers with this process. Most of the transformers were located in Quebec, however, several were located in Nova Scotia and Manitoba.

The surface contamination levels set by Environnement Québec in the Decontamination Guidelines of October 1985 are 1.25 mg/m^2 for Arochlor 1260 and 1254 and 2.5 mg/m^2 for 1242. The levels apply only to the transformer casing. To determine if the core of the transformer has been successfully decontaminated, the core is sampled and the sample is soaked in solvent to remove residual PCBs. The concentration of PCBs in the core can then be determined based on the weight ratios of each component of the core. Sanexen, in conjunction with S.D. Myers, has determined the weight ratios in previous studies. If the core contains ≤50 ppm, it can be sent for metal recovery and subsequent smelting.

Currently, Sanexen has mobile transformer decontamination units operating in Quebec and Manitoba. Mobilization requires about 2 days and demobilization takes 1 day. The cost of decontamination depends on whether the transformer contained mineral oil or askarel, the size of the transformer, and the number of transformers to be treated in one location.

Sanexen estimates its prices range from $1.54 to $5.50 (Cdn.)/kg. At the moment, an

additional sum of about $4000.00 (Cdn.) is required to obtain site-specific approval for each client.

E.2 Decontamination for Landfilling

In the United States, transformer carcasses that contain PCB liquids with >500 ppm PCBs must be drained then filled with an approved solvent and allowed to sit for 18 hours. Once the solvent has been drained, the carcass can be taken to an approved chemical waste landfill.